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**Upgrade of the Ballistic Range Facilities at  
AEDC: Now Completed**

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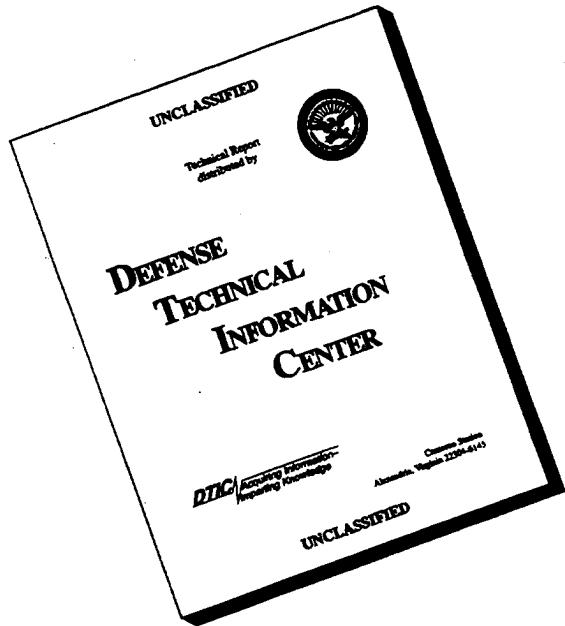
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# UPGRADE OF THE BALLISTIC RANGE FACILITIES AT AEDC: NOW COMPLETE\*

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## Abstract

This paper discusses the completion of the planned upgrading of the ballistic range facilities at AEDC. The AEDC Hypervelocity Testing Complex consists of (1.) a large 3.3-in.-bore two-stage light-gas launcher providing soft launch of models into the existing 930-ft-long Range G, with track guidance and model recovery, operational since April 1994; (2.) a 2.5-in.-bore two-stage light-gas launcher with performance comparable to the former Range G, launching models into a dedicated Impact Range which has been operational since January 1993; and (3.) a high-performance free-piston shock tunnel designed for stagnation pressures of 10,000 atm and stagnation temperatures of 10,000°K, operating at pressures up to 1,400 atm since April 1993.

## Background

For over 30 years, AEDC has operated the 1,000-ft-long Aeroballistic Range G, now the premier hyperballistic facility operating in the USA. The closure of the other major range at Delco, Santa Barbara, on July 1, 1988, triggered a review of the future plans for Range G, which led to the upgrade of the ballistic capabilities which will now be described.

## Capability Up to April 1993

The 1,000-ft-long Range G (Fig. 1) used a 2.5-in.-bore two-stage light-gas launcher to launch models at velocities up to 24,000 ft/sec (7.3 km/sec). In-gun weights (model + sabot) launched ranged from 0.35 lb (160 gm) to 7.0 lb (3,200 gm). The 1,000-ft range was equipped with up to 45 orthogonal

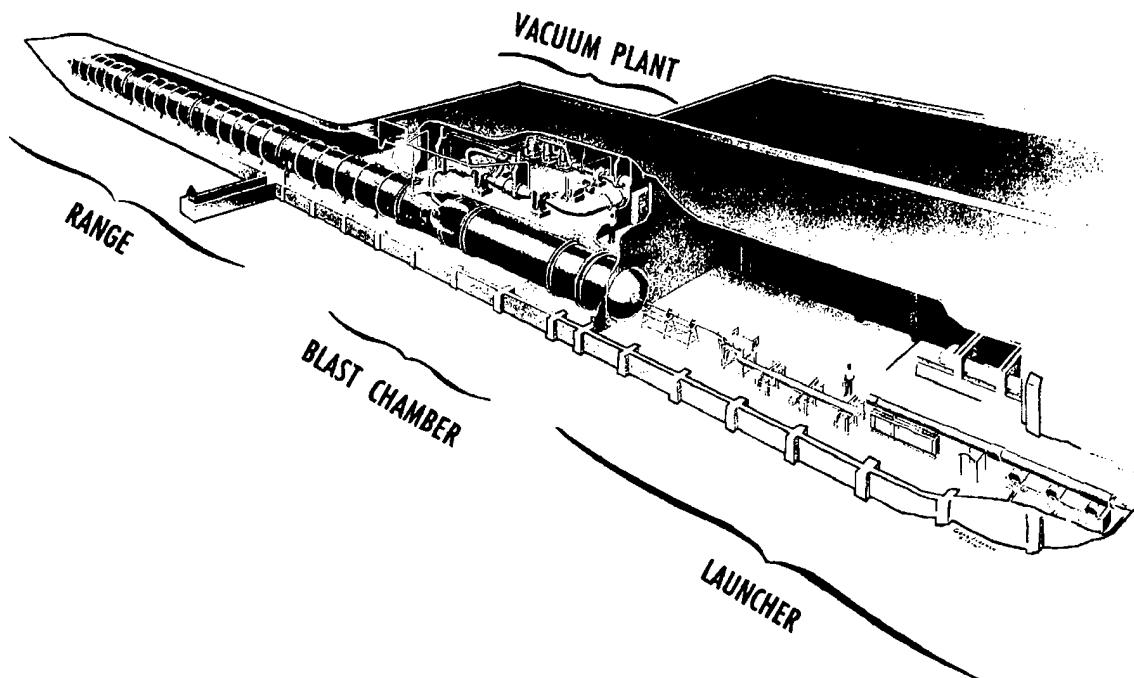


Fig. 1. Former AEDC Hypervelocity Range/Track G.

\*The research reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Materiel Command. Work and analysis for this research were done by personnel of Calspan Corporation/AEDC Operations, technical support contractor for the AEDC aerospace flight dynamics facilities. Further reproduction is authorized to satisfy needs of the U. S. Government.

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spark shadowgraph stations for the determination of aerodynamic trajectories, thirteen x-ray shadowgraphs, eleven front-light back-light laser photographic stations, and many other special instruments.

The types of free-flight testing performed are listed in Table 1.

Table 1. Types of Free-Flight Test

ABLATION
ABLATION/EROSION
TCNT
BOUNDARY-LAYER TRANSITION
HEAT TRANSFER
AERODYNAMICS
ROCKET CONTRAIL
REENTRY PHYSICS
IMPACT
CANNON PROJECTILE

Additionally, Range G had a unique track and recovery capability. A four-rail track (see Fig. 2) spanned the length of the range. At the end of the instrumented range tank, the track led into a 500-ft-long closed tube in which compressed gas slowed the hypervelocity model until it came to rest in a tapered rail section. This recovery capability allowed recovery of models after they flew through erosive environments such as dust and snow.

Table 2 is a listing of the types of testing which were performed using track and recovery.

Table 2. Types of Track Test

ABLATION
ABLATION/EROSION
TCNT
HEAT SHIELD & ANTENNA WINDOWS
BOUNDARY-LAYER TRANSITION
GAS JET
SINGLE IMPACT
TELEMETRY - ONBOARD
TELEMETRY - OFFBOARD
HIGH G ACCELERATION

#### 1989 Review of Requirements

As reported previously (Refs. 1-4), the closure of the Delco Range in 1988 led to a review of future range requirements at AEDC. In 1989, wake testing was a major requirement, for which a clean range is necessary. It was decided to move impact testing from the 1,000-ft Range G to a new, shorter, dedicated Impact Range. A second requirement was a "softer" launch for fragile models. "Softer" launch refers to reducing the peak acceleration experienced by the model during launch. For example, a 550-gm (1.2-lb) model launched by the 2.5-in. two-stage light-gas launcher in Range G experiences peak acceleration of 186,000 g's. A goal was then set to design a launcher with as soft a launch as possible within the restriction that it should fit in the existing building.

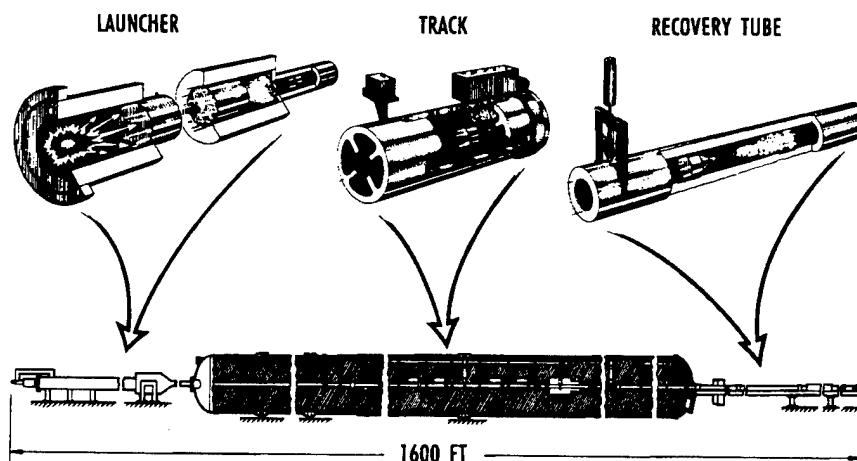


Fig. 2. Hypervelocity Track G.

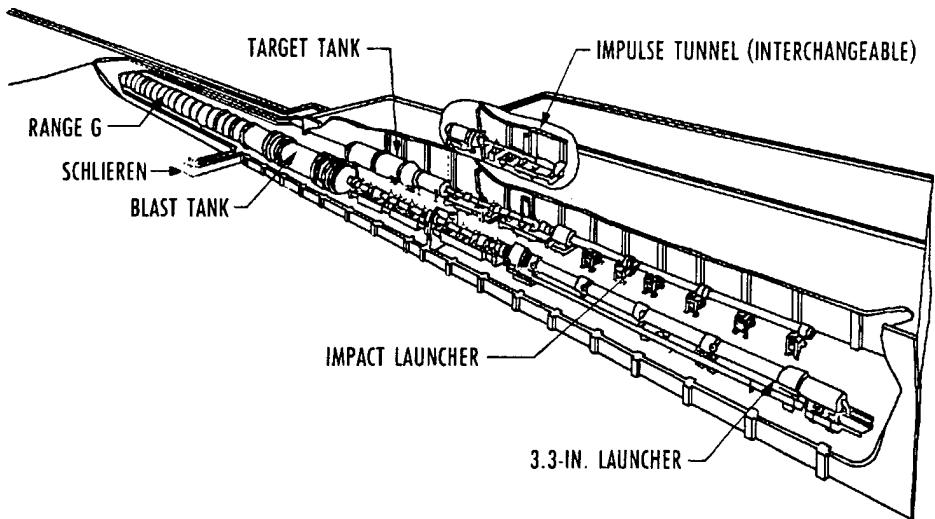


Fig. 3. Upgraded ballistic range capability.

### The Concept

As reported previously (Refs. 1-4), the upgrade concept consists of three parts (1) replacing the 2.5-in. two-stage light-gas launcher with a 3.3-in. bore soft launcher capability and increasing the track and recovery capability to 3.3 in.; (2) installing a dedicated Impact Facility with a similar 2.5-in. bore launcher to the existing launcher; and (3) being able to replace the 2.5-in. launch tube with a 3.0-in. bore shock tube, nozzle, and test section. Figure 3 is the artist's concept of these three test facilities.

### Status of Upgrade

As reported in January 1994 (Ref. 4), the Impact Facility (Fig. 4) and the Impulse Tunnel (Fig. 5) were

operational. Calibration of the Impulse Facility will be described in another paper<sup>5</sup> at this meeting.

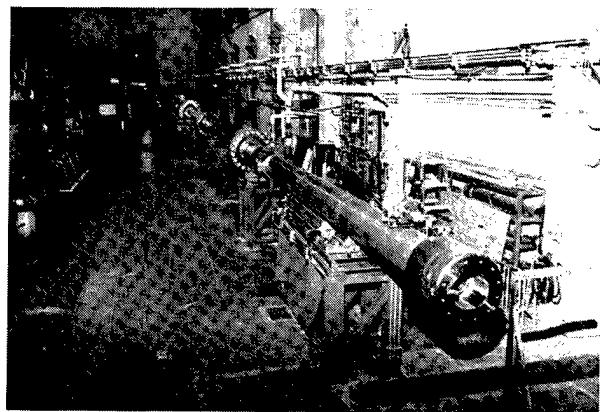


Fig. 4. The impact launcher.

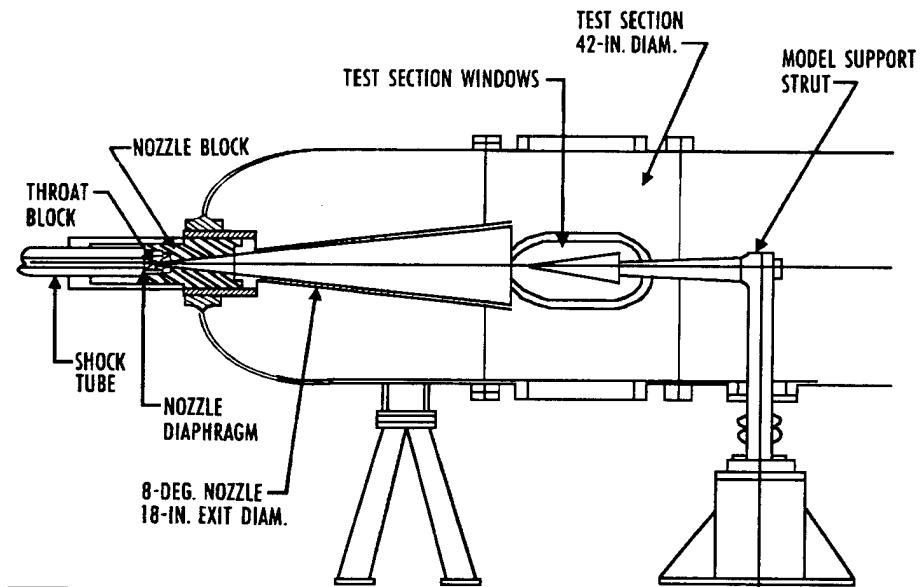


Fig. 5. Test section and model support for Impulse Tunnel.

The 3.3-in. launcher is now complete and checkout firings have been made. Figure 6 shows the powder chamber and breech plug installed. The breech plug is inserted and withdrawn mechanically, and can be swung out to the side for loading the powder charge. The powder chamber can be moved axially and laterally for piston loading and pump tube cleaning. Figure 7 shows the powder chamber attached to the pump tube and also the powder loader holding the basket which contains the powder charge. The piston loader, which moves on air bearings, is used to load pistons weighing up to 2,500 lb.

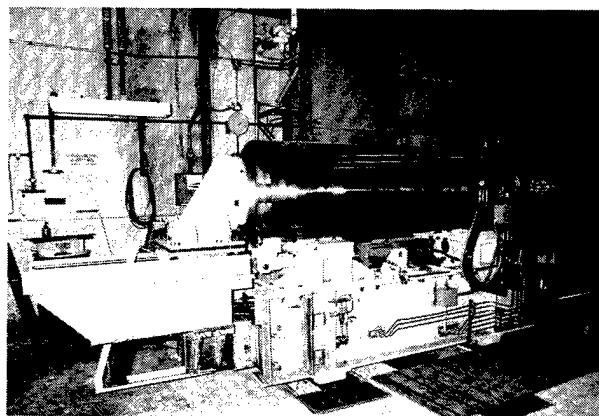


Fig. 6. Powder chamber and breech plug.

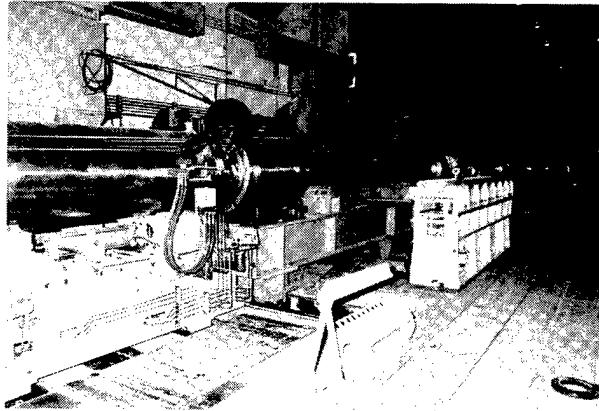


Fig. 7. Powder chamber with powder and piston loaders.

Figure 8 shows one of the four 25-ft-long sections of the 14.0-in.-bore pump tube. Figure 9 shows the high-pressure section in which the piston comes to rest. It is contained in a 60,000-lb mass addition to reduce recoil movement. Figure 10 shows the 100-ft-long, 3.3-in.-bore launch tube on its steady rests. The steady rests are attached to a mount which can be moved on air bearings to change out launch tube sections. One of the air bearings can be seen at the center bottom of the figure. The launch tube is honed between shots with an automatic 100-ft-long hone. This can be seen alongside the pump tube in Fig. 11.

Figure 12 shows plots of the computed acceleration of a 2-lb model to 19,500 ft/sec compared with the accelerations measured using a microwave reflectometer. The computed peak acceleration is 78,000 g's and the measured value is 85,000 g's. A Visar loaned to AEDC by Sandia National Laboratories gave similar acceleration measurements, but the data reduction method has not been sufficiently refined yet to give other than peak g's.

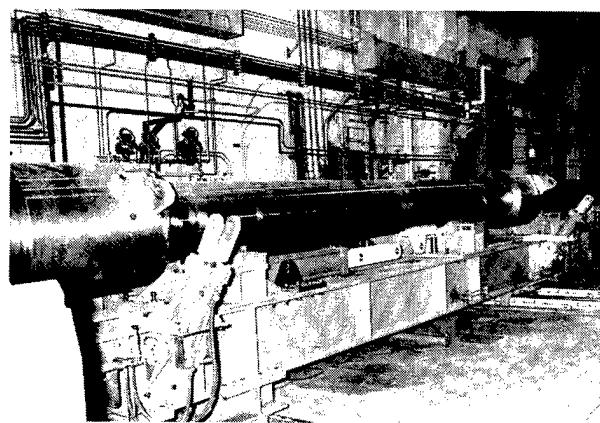


Fig. 8. Pump tube.

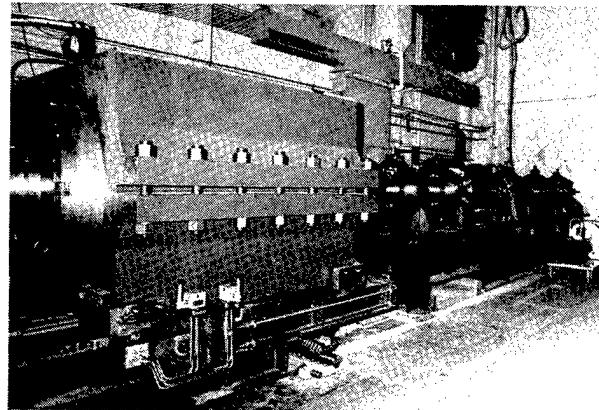


Fig. 9. High-pressure section and mass addition.

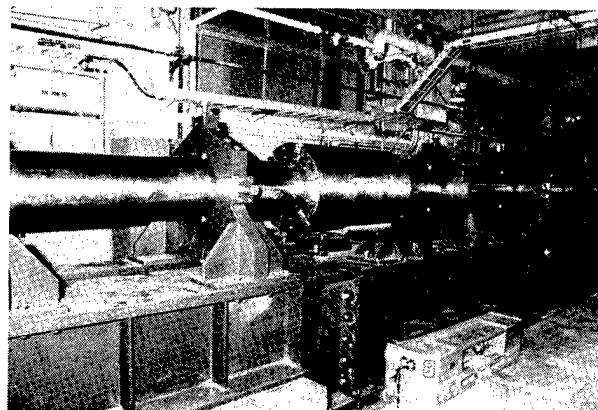


Fig. 10. Launch tube.

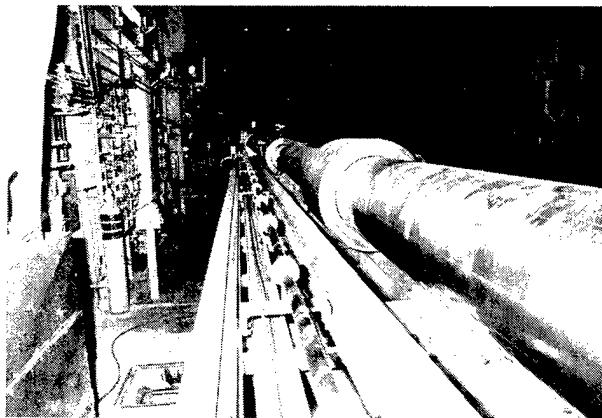


Fig. 11. Launch tube hone alongside pump tube.

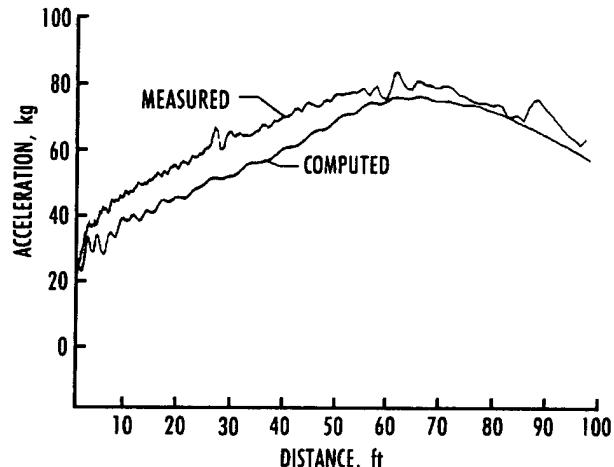


Fig. 12. Launch accelerations, measured and computed for 2-lb model at 19,500 ft/sec.

Figure 13 shows the throw weight capability predicted for the 3.3-in. launcher. Also shown is the design point 2 lbs at 19,000 ft/sec. Two shots made at the design condition gave velocities of 19,520 and 19,140 ft/sec. Figure 14 shows a laser photograph of a 2-lb. telemetry model flying at 19,140 ft/sec.

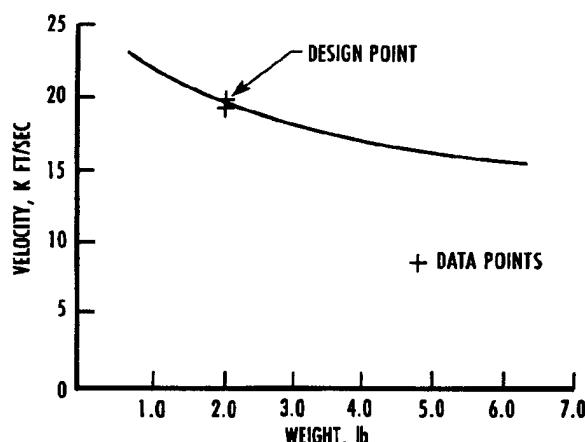


Fig. 13. Throw weight capability.

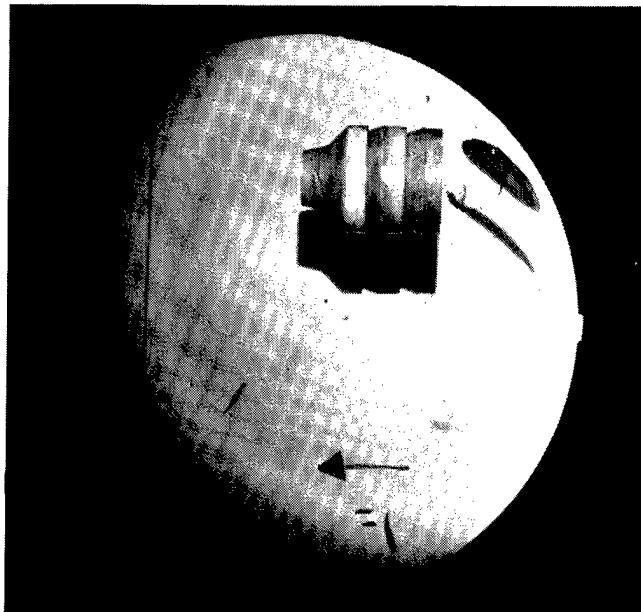


Fig. 14. Telemetry model launched at 19,140 ft/sec.

Checkout shots with the track and recovery systems are planned for late May 1994.

### Summary

The dedicated Impact Facility with its 2.5-in. two-stage hypervelocity launcher and Impulse Tunnel with its 18-in. exit diameter nozzle have been operational for over a year. The new 3.3-in. launcher with its very soft launch is now operational. These upgraded facilities provide AEDC with the premier hypervelocity test complex in the world.

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